1997

Micro-Macro Behavior near the Crack Tip in a Particulate Composite Material

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In recent years, a considerable amount of work has been done in studying crack growth behavior in highly filled polymeric materials [1-4]. The importance of these studies stems from the fact that the crack growth behavior in the material may significantly affect the integrity of the structure made of that material. The basic approach used in characterizing the particulate composite material is based on linear elastic or linear viscoelastic fracture mechanics. According to the theories, crack growth behavior is controlled by the local stress/strain near the crack tip. Therefore, the values of local stress/strain near the crack tip must be determined.

When crack occurs, the high stress at the crack tip will induce high damage near the crack tip region. The high damage zone at the crack tip is defined as the failure process zone, which is a key parameter in viscoelastic fracture mechanics. Experimental data reveal that when the local strain reaches a critical value, small voids are generated in the failure process zone. Due to the random nature of the microstructure, the first void is not necessarily formed in the immediate neighborhood of the crack tip. The formation of the voids is not restricted to the surface of the specimen where the maximum normal strain occurs. Since the tendency of the filler particle to separate from the binder under a triaxial loading condition is high, it is expected that voids or damage zones will be generated in the specimen's interior. Consequently, there are a large number of strands, which separate the voids and are essentially made of the binder material, that form inside the failure process zone (Fig.1). These damage processes are time-dependent and are the main factor responsible for the time-sensitivity of strength degradation as well as fracture behavior of the material.

In addition to the damage analysis, the strain fields within a 1.5 mm region near the crack tip were determined using a digital image correlation technique. Experimental findings reveal that the heterogeneity of the microstructure plays a key role in the local damage and strain distribution near the crack tip (Figure 2). Figure 2 shows that the strain fields are highly inhomogeneous and that the high strain regions are localized in the neighborhood of the crack tip. Depending on the location of the high strain regions, voids may develop in these regions and coalesce with the crack tip, resulting in growth of the crack. The crack-void interaction is a contributing factor to the fluctuation of crack growth behavior in this material. Experimental results also reveal that local strain rates are significantly higher than the applied strain rate and that these high strain rate regions are localized to a distance within a 1 mm region of the crack tip

In conclusion, the heterogeneity of the microstructure plays a key role for local damage and strain distributions near the

crack tip. Experimental results indicate that the high strain field is localized within 1 mm of the crack tip. Also, the time - dependent damage initiation and evolution processes are contributing factors to the nonsteady crack growth in this material.

References

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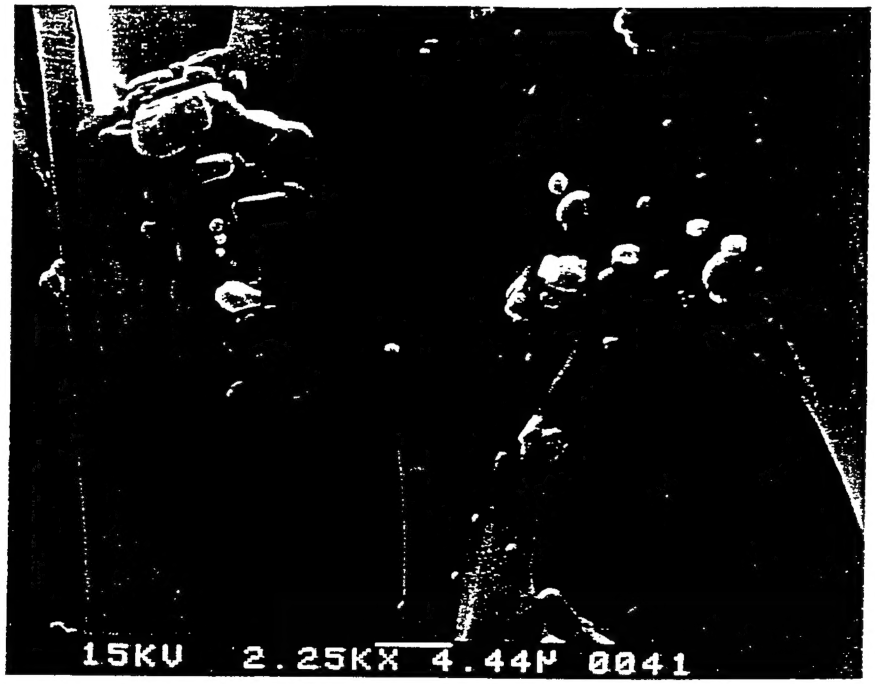

Figure 1. Damage zone at crack tip.

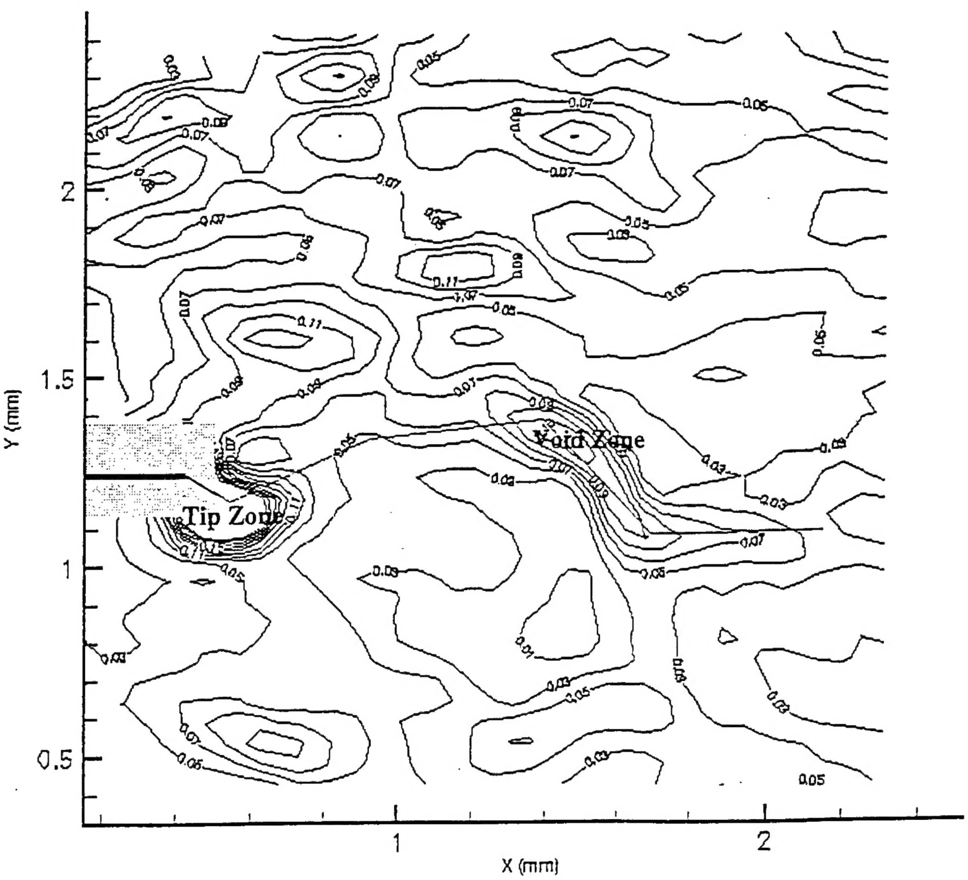

Figure 2. Maximum principal strain distribution at 6% applied strain.